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(71) Applicant: SEIKO INSTRUMENTS INC.
Chiba-shi, Chiba 261 (JP)

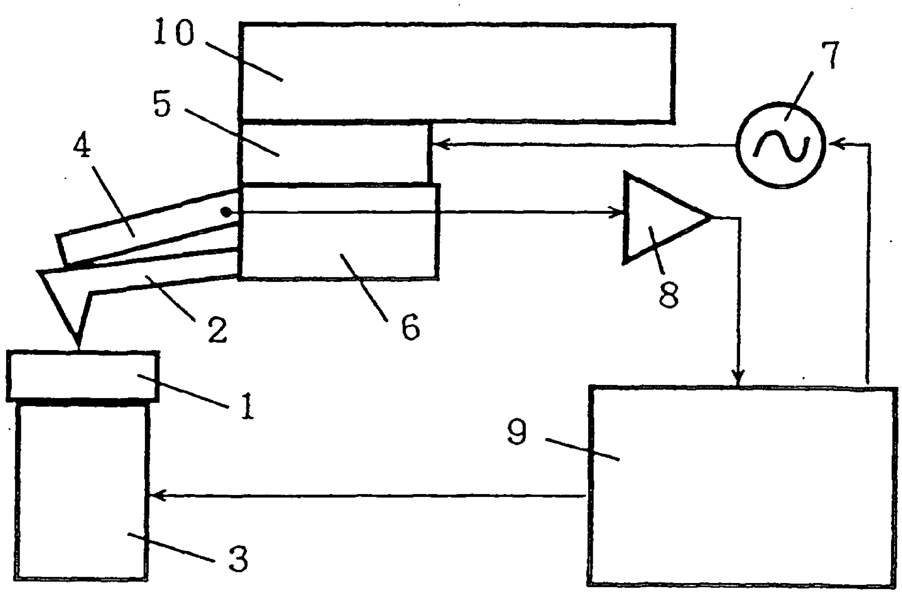
(72) Inventors:
- Muramatsu, Hiroshi
  Mihama-ku, Chiba-shi, Chiba (JP)
- Tomita, Eisuke
  Mihama-ku, Chiba-shi, Chiba (JP)

(74) Representative: Sturt, Clifford Mark et al
Miller Sturt Kenyon
9 John Street
London WC1N 2ES (GB)

(54) Scanning probe microscope

(57) A cantilever for a probe and a piezoelectric cantilever for detecting displacement of the probe are separately installed to a scanning probe microscope, either or both of the cantilever for the probe and the piezoelectric cantilever for detecting displacement of the probe are oscillated by using oscillating means and a force exerted on the probe is detected as a change in resonance characteristic of the piezoelectric cantilever for detecting displacement.

FIG. 1



EP 0 896 201 A1

Description

[0001] The present invention relates to a scanning type atomic force microscope for observing the shape of the surface of a sample as well as a scanning probe microscope for observing surface physical properties by scanning a probe along the surface of the sample by utilising the force exerted between substances (that is, force exerted between the probe and sample).

[0002] According to a conventional scanning type atomic force microscope, by using a cantilever formed of silicon nitride or silicon and a stylus formed thereon as a probe for the atomic force microscope, an atomic force exerted between a front end of the stylus and the surface of the sample is detected as bending of the cantilever, a change in an oscillation amplitude or a change in resonance frequency. The surface of the sample is observed by moving the stylus and the sample relative to each other while controlling the distance between the front end of the stylus and the surface of the sample to be constant. As another control method, there is a control method of the shear force system where the probe is oscillated horizontally in respect of the surface of the sample. An optical method such as an optical lever method, an optical interference method or the like is mainly used for detecting the displacement of the cantilever. When such an optical method is used, the constitution of the device becomes complicated and adjustment of an optical axis or the like is needed which makes handling of the device complicated.

[0003] With respect thereto, a cantilever incorporating a piezoelectric detecting mechanism which electrically detects oscillation has been described in Japanese Unexamined Patent Publication No. JP-A-5-196458 and Japanese Unexamined Patent Publication No. JP-A-6-323845.

[0004] Further, a proposal in which a quartz oscillator is used as a probe for an atomic force microscope has been described in Japanese Unexamined Patent Publication No. JP-A-63-309803 and Japanese Unexamined Patent Publication No. JP-A-4-102008.

[0005] Further, a method of carrying out nonoptical detection by integrating a tuning fork type quartz oscillator and an optical fiber for constituting a scanning type near-field microscope has been disclosed in Japanese Unexamined Patent Publication No. JP-A-9-89911.

[0006] According to each of the detecting methods which do not utilise optical means it is necessary to integrally form the piezoelectric element and the probe and a problem arises in the case where a portion of the probe is damaged or malfunctions the whole of the probe must be interchanged. Particularly, in the process of fabricating the probe, when a fixing operation such as adhesion or the like is carried out, a problem also arises in the reproducibility of dynamic properties.

[0007] Further, when static bending of the probe is detected, drift of a base signal included in a static signal occurs as a problem in control.

[0008] Further, acquisition of function information other than shape information in a nonoptical detecting system is also an important problem.

[0009] It is an object of the present invention to provide a scanning probe microscope wherein by separately preparing the probe portion for scanning the surface and the piezoelectric cantilever element for detecting the displacement of the probe, the shape of the surface of the sample can be electrically measured without using a conventional optical detecting method and the cost of the probe, which is a consumable article, can be reduced or kept low.

[0010] It is another object of the present invention to provide a scanning probe microscope wherein even in the case where the shape of the surface of the sample is measured by a static control system, the detection can be carried out by an alternating current signal and therefore stable control of the signal can be performed without being influenced by drift.

[0011] It is a further object of the present invention to provide a scanning probe microscope wherein observation of function information other than shape information can be carried out in a nonoptical detection system using a piezoelectric element.

[0012] Embodiments of the present invention will now be described by way of further example with reference to the accompanying drawings, in which:-

Fig. 1 is an explanatory view of a scanning probe microscope according to the present invention;
Fig. 2 is an explanatory view of the operational principle of a scanning probe microscope according to the present invention;
Fig. 3 is an explanatory view of the operational principle of a scanning probe microscope according to the present invention;
Fig. 4 is an explanatory view of the operational principle of a scanning probe microscope according to the present invention;
Fig. 5 is an explanatory view of a scanning probe microscope according to the present invention;
Fig. 6 is an explanatory view of a scanning probe microscope according to the present invention;
Fig. 7 is an explanatory view of a scanning probe microscope according to the present invention;
Fig. 8 is an explanatory view of a scanning probe microscope according to the present invention;
Fig. 9 illustrates explanatory views of probes in a scanning probe microscope according to the present invention;
Fig. 10 is an explanatory view of a probe used in a scanning probe microscope according to the present invention;
Fig. 11 is an explanatory view of a scanning probe microscope according to the present invention; and
Fig. 12 is an explanatory view of a scanning probe microscope according to the present invention.

[0013] In order to resolve the above-identified problems, according to the present invention, there is provided a scanning probe microscope in which a cantilever probe is closely arranged on a surface of a measurement object. The cantilever probe is relatively scanned two-dimensionally on the surface of the measurement object by using a three-dimensional fine movement element thereby observing surface shape or surface physical properties of the measurement object. At least as means for detecting a displacement of the cantilever probe, a sensor cantilever is installed at a distance touchable to the cantilever, apart therefrom and separately from the cantilever probe. In the microscope, oscillating means for oscillating either or both of the cantilever probe and the sensor cantilever is installed. Distance control between the cantilever probe and the surface of the measurement object is carried out by a change in resonance characteristic of the sensor cantilever. The cantilever probe can be operated by being separated from the cantilever means and nonoptical detection for detecting the displacement by an electric signal is made possible by using a piezoelectric element in the sensor cantilever. Further, the resonance frequency of the sensor cantilever is made higher than the resonance frequency of the cantilever probe. The cantilever probe is provided with a bending moment by being brought into dynamic equilibrium between the surface of the measurement object and the oscillating sensor cantilever by which a change in resonance characteristic of the sensor cantilever occurs. Static bending of the cantilever is detected as an alternating current signal. The static force exerted between the cantilever probe and the surface of the measurement object is detected and the distance control between the front end of the probe and the surface of the measurement object can be carried out.

[0014] The resonance frequency of the cantilever probe is made higher than the resonance frequency of the sensor cantilever. The probe cantilever is oscillated at the same frequency as that of the oscillating sensor cantilever and by a change in the resonance characteristic of the sensor cantilever, the distance control between the front end of the cantilever probe and the surface of the measurement object is carried out; by which the distance control of the probe in an oscillation mode is made possible.

[0015] Further, according to the microscope of the present invention, by providing a position adjusting function, contact pressure between the cantilever probe and the sensor cantilever can arbitrarily be changed and the operational characteristic of the probe can be adjusted to be optimum.

[0016] An optical wave guide is included at a portion of the cantilever probe and is constituted such that one end face of the wave guide coincides with the front end of the probe for observing function information by which the observation of optical information is made possible. Further, piezoelectric detecting means is provided on the cantilever probe. This outputs a signal identifying displacement of the probe independently from the signal of the sensor cantilever, by which observation of information of the surface physical properties is made possible.

[0017] An explanation will be given of embodiments of the present invention with reference to the accompanying drawings as follows.

[0018] Fig. 1 shows an example of the constitution of a scanning probe microscope according to the present invention. According to the constitution of Fig. 1, a cantilever probe 2 is arranged closely on the surface of a measurement object 1 and a three-dimensional fine movement element 3 provides two-dimensional scanning of the surface of the measurement object 1. Thereby, the surface shape or surface physical properties of the measurement object can be observed. As means for detecting displacement of the cantilever probe 2, a sensor cantilever 4 is installed on a support 6 separately from the cantilever 2, apart therefrom and at a distance touchable to the cantilever probe 2. In this case, "touchable" indicates a state where they are originally brought into contact with each other or where they are separated from each other by a distance where they can be brought into contact with each other by oscillation. Oscillating means 5 is driven by an alternating current voltage source 7 and oscillates either one or both of the cantilever probe 2 and the sensor cantilever 4. A change is resonance characteristic of the sensor cantilever 4 which is dependent on the distance between the cantilever probe 2 and the surface of the sample 1, is input in to a control device 9 via an amplifier 8. The control device 9 can control the distance between the probe and the surface of the measurement object by controlling the fine movement element 3 based on the change in the resonance characteristic.

[0019] In detecting the displacement of the sensor cantilever 4 of the scanning probe microscope, the conventional optical detection system may be used or the displacement may be detected as an electric signal by using a piezoelectric detection element at the sensor cantilever 4.

[0020] Further, the device constitution diagram shown by Fig. 1 describes the major component according to the present invention. In actual reduction to practice of the present invention, constituent elements which are generally used in the probe microscope other than those described in Fig. 1 are included.

[0021] Next, an explanation will be given of a detailed operational system with reference to Fig. 2 through to Fig. 6.

[0022] Fig. 2 is a view for explaining the operation in the case where the resonance frequency of the sensor cantilever 4 is set higher than the resonance frequency of the cantilever probe 2. By the resonance oscillation of the sensor cantilever 4, the cantilever probe 2 is provided with a bending moment caused by being brought into dynamic equilibrium between the oscillating sensor

cantilever 4 and the surface of the measurement object 1. By the bending of the cantilever probe 2, the resonance characteristic of the sensor cantilever 4 is changed. Based on the change in the resonance characteristic, a static force exerted between the cantilever probe 2 and the surface of the measurement object 1 can be detected and the distance control can be carried out between the front end of the probe and the surface of the measurement object. That is, the cantilever probe 2 cannot follow the oscillation of the sensor cantilever 4 and therefore, only the sensor cantilever 4 is oscillated and continuously repeats collision with the cantilever probe 2. The cantilever probe 2 is provided with constant bending by the continuous collision. In this case, according to the sensor cantilever 4, owing to the collision with the cantilever probe 2, the amount of oscillation is reduced compared with free oscillation in the resonance state and the phase of oscillation is also changed. When the cantilever probe 2 is brought close to the surface of the measurement object 1, attractive force or repulsive force by operation of atomic force arises between the cantilever probe 2 and the measurement object 1. When attractive force is exerted on the cantilever 2, the amplitude of oscillation of the sensor cantilever 4 is increased and when repulsive force is exerted thereon, the amplitude of oscillation of the sensor cantilever 4 is reduced. In this way, by this system, in a so-called contact mode AFM for detecting the static bending of the cantilever probe, the distance control between the sample-probe can be carried out by an alternating current signal. However, according to the control system, it is preferable to prevent a frequency inducing a higher order resonance mode in the cantilever probe from coinciding with the resonance frequency of the sensor cantilever. When the number of the order is increased, the influence is reduced. In respect of the resonance frequency of the cantilever probe, apparent resonance frequency is increased by pressure exerted by the sensor cantilever. Accordingly, the resonance frequencies of the two cantilevers need to be set sufficiently different from each other in consideration thereof.

[0023] Fig. 3 is a view showing a constitution for detecting twist of the cantilever probe in the contact mode operation mentioned above. In the contact mode operation, in the case where the cantilever probe is twisted by friction with the sample, light from a light source is reflected by the twisted cantilever probe 2. Reflected light is detected by optical detecting means 11 and an amount of twist is detected by which friction information of the sample surface can be observed. Although as twist detecting means, as shown in Fig. 3, the optical detecting means 11 such as an optical lever method can be used, a piezoelectric detecting system mentioned later can also be used.

[0024] Fig. 4 is a view showing a constitution in which the substantial resonance frequency of the cantilever probe 2 is set to be higher than the resonance frequency of the sensor cantilever 4. The probe cantilever 2 is oscillated at the same frequency as that oscillating the sensor cantilever 4 and the distance control between the front end of the cantilever probe 2 and the surface of the measurement object 1 is carried out by the change in the resonance frequency of the sensor cantilever 4, by which the distance control of a so-called dynamic mode system can be carried out.

[0025] In carrying out the dynamic mode operation, means for detecting the phase and the amplitude of the cantilever probe 2 is provided independently from the sensor cantilever 4. The displacement signal of the sensor cantilever 4 is compared with the displacement signal of the cantilever probe 2 by which a so-called phase image can be provided. Further, as a method of obtaining function information of viscoelastic information of the surface of the sample 1 or the like, since in the atmosphere there is the influence of adsorbed water, a change in phase which is dependent on viscoelasticity inherent to the sample can be obtained by setting the amplitude of oscillation of the cantilever probe 2 to about several nanometers such that the front end of the probe is always prevented from leaving the adsorbed water whereby viscoelastic information can be obtained.

[0026] As means for oscillating the cantilever probe 2 and the sensor cantilever 4, these cantilevers can be oscillated by applying an alternating current signal to the piezoelectric element 5. The cantilever probe 2 and the sensor cantilever 4 are fixed onto the same support 6 and the piezoelectric element 5 is oscillated at a frequency near to the resonance frequency of the sensor cantilever 4, by which the sensor cantilever 4 is resonated and its oscillation amplitude can be made larger than that of the cantilever probe 2. In this case, similar operation is shown as in the case where only the sensor cantilever 4 is oscillated by a piezoelectric element as shown in Fig. 5. Fig. 5 is a view showing a constitution where the cantilever probe 2 is supported by the support 10 and only the sensor cantilever 4 is oscillated by the piezoelectric element 5.

[0027] In the case of the contact mode operation mentioned above, a change in the distance between the sensor cantilever 4 and the cantilever probe 2 or a change in contact pressure therebetween is caused based on the bending of the cantilever probe 2 and the change can be detected as a change in amplitude or a change in phase of the sensor cantilever 4. The surface shape of the measurement object 1 can be observed by controlling the fine movement element 3 comprising the piezoelectric element by the control device 9 which controls the amount of the displacement constant by a feedback control.

[0028] In the case where the resonance frequency of the sensor cantilever is higher than that of the cantilever probe mentioned above, there is a case where an adhering force for adhering the probes may be caused between the cantilever probe and the sensor cantilever due to adsorbed water on the surface or the like. In this case, the force is received by the sensor cantilever in a

direction in which the cantilever probe leaves the face of the sample and the bending of the cantilever probe cannot be accurately detected. In order to avoid such a problem, hydrophobic treatment is carried out in respect of both sides or one side of portions where the cantilever probe and the sensor cantilever are brought into contact with each other, by which the problem can be avoided. As the hydrophobic treatment method, there can be used a general method where a molecule having a hydrophobic radical is directly chemically bonded or physically adsorbed onto the portion such that the hydrophobic radical is directed to the outer side.

[0029] In the case of the dynamic mode operation mentioned above, the cantilever probe 2 is oscillated at the same frequency by the sensor cantilever 4 and the force exerted on the cantilever probe 2 is indirectly detected as a change in the amplitude or the phase of oscillation. In this case, as means for oscillating the cantilever probe 2 and the sensor cantilever 4, there is a system where the cantilever probe 2 and the sensor cantilever 4 are fixed onto the same holder 6 and the sensor cantilever 4 is resonated by oscillating the piezoelectric oscillator 5 at a frequency near to the resonance frequency of the sensor cantilever 4. Also there is a system where only the sensor cantilever 4 is oscillated by the piezoelectric oscillator 5 and the cantilever probe 2 is oscillated by the sensor cantilever 4. Further, Fig. 6 shows a constitution in which only the cantilever probe 2 connected to the support 6 is oscillated by the piezoelectric element 5 by which the sensor cantilever 4, the end of which is brought into contact with the cantilever probe 2, is oscillated. Thereby, there can be adopted a system where the displacement of the cantilever probe 2 is detected as a change in the oscillation of the sensor cantilever 4.

[0030] Fig. 7 is a view showing a constitution in which a position adjusting mechanism 12 is installed to the device constitution described with reference to Fig. 1 through Fig. 6. By providing the position adjusting mechanism 12, the contact pressure between the cantilever probe 2 and the sensor cantilever 4 can arbitrarily be changed. Thereby, adjustment can be carried out such that the measurement is performed under an optimum condition.

[0031] As a piezoelectric element used in the sensor cantilever 4 according to the present invention, there is a piezoelectric ceramics element of PZT or the like having the piezoelectric characteristic in the thickness direction or a piezoelectric element of a bimorph type having the piezoelectric characteristic in the bending direction, where two sheets of films having the piezoelectric characteristic in the lateral direction are pasted together. Further, there is a method where a change in the resistance of silicon doped with ZnO or an impurity or the like is used. Also, there is a method where the bending oscillation of a quartz oscillator is used. In the case of a quartz oscillator, the bending oscillation of an X plate quartz oscillator or a turning fork type quartz oscillator is utilised and electric charge generated at an electrode of the quartz oscillator can be used as a control signal by amplifying it by the amplifier 8.

[0032] Next, a detailed description will be given of a method of observing function information other than shape information of the surface of the sample simultaneously with measuring the shape of the surface of the sample. In respect of the measurement of the shape of the surface of the sample, a description has been given above and an explanation thereof will be omitted here. In the following, an explanation will be given of a method of observing function information other than the information of the shape of the surface of the sample.

[0033] First, observation of optical information can be realised by constituting a cantilever probe including an optical wave guide at a portion of the cantilever probe such that one end face of the wave guide coincides with the front end of the probe.

[0034] Fig. 8 is a view showing an example of a constitution in the case where a probe comprising an optical fiber is used as a probe having a wave guide. In the drawing, an optical fibre probe 13 is provided with a metallic coating at a portion thereof operating as a cantilever, except a front end portion disposed closely to the surface of the measurement object 1. A very small opening is formed at the front end portion. Light from a light source 15 can be introduced via a lens 14 to an end face of the optical fiber on a side opposed to the probe portion of the optical fiber. Meanwhile, light scattered by the surface of the sample 1 can be detected by an optical detector 17 via a lens 16 arranged to focus on the front end of the probe. A constitution where the arrangement of the optical detector 17 and the light source 15 is reverted and light is picked up from the front end of the probe is also possible. An example where a tuning fork type quartz oscillator 18 is used as the sensor cantilever is shown.

[0035] Physical property information of the surface of the sample can be obtained by measuring the oscillation characteristics of the cantilever probe 2 and the sensor cantilever 4 mentioned above separately from each other. A probe having piezoelectric detecting means in the cantilever probe 2 may also be used. According to this system, as shown in Fig. 9A, signals are detected by arranging piezoelectric elements 19 of a bimorph type in parallel on the cantilever probe and reversing polarities thereof such that the signals are output in respect of twist of the cantilever probe 2. Observation of fraction information of the surface can be carried out by subjecting the output signals to signal processing via the amplifier 8. According to the constitution, the directions of bending of the two piezoelectric elements are reversed by the twist of the cantilever probe 2. Accordingly, electric charge is generated in respect of the twist.

[0036] As shown in Fig. 9B, the detection of the twist can be carried out also by arranging a piezoelectric resistor 20 vertically to the longitudinal direction of the cantilever 2.

[0037] When a piezoelectric element 21 is arranged simply on the cantilever probe 2 as shown by Fig. 10, physical property information such as viscoelasticity or the like can be detected by outputting displacement signals of the probe such as phase, amplitude and the like independent from the signal of the sensor cantilever 4.

[0038] According to the embodiments mentioned above, a description has been given of a system where a major spring element portion included in the cantilever probe 2 is arranged substantially horizontally to the surface of the measurement object 1 and a deflection between the two in the distance direction is detected, by which the force exerted in the distance direction is sensed and the distance control between the sample and probe is carried out.

[0039] Fig. 11 shows a constitution where a major spring element portion included in the cantilever probe is arranged substantially vertically to the surface of the measurement object. There can be provided a constitution where shear force exerted between the front end of the cantilever probe 1 and the surface of the measurement object 1 (illustration is omitted) is sensed by which the distance control between the sample-probe is carried out. Fig. 11 illustrates an example where the optical fiber probe 13 of a straight type is used as a cantilever probe and the tuning fork type quartz oscillator 18 is used as the sensor cantilever.

[0040] Fig. 12 illustrates an example constituted by bringing the cantilever probe 2 and the sensor cantilever 4 into contact with each other while they intersect each other at an angle. By bringing the cantilever probe 2 and the sensor cantilever 4 into contact with each other while they intersect at an angle, the contact position can be made difficult to shift.

Claims

1. A scanning probe microscope in which a cantilever probe (2) is arranged to be positioned close to a surface of an object to be measured and the cantilever probe and the surface of the object are scanned relative to each other, wherein a separate sensor cantilever (4) for detecting a displacement of the cantilever probe (2) is provided so as to be contactable with the cantilever probe (2).

2. A scanning probe microscope as claimed in claim 1, further comprising oscillating means (5) for oscillating either or both of the cantilever probe (2) and the sensor cantilever (4), wherein distance control between the probe and the surface of the object is carried out by detecting a change in the resonance characteristic of the sensor cantilever.

3. A scanning probe microscope as claimed in claim 1, wherein the sensor cantilever (4) comprises a piezoelectric element and the displacement is detected based on an output signal from the piezoelectric element.

4. A scanning probe microscope as claimed in claim 2, wherein the resonance frequency of the sensor cantilever (4) is made higher than the resonance frequency of the cantilever probe (2).

5. A scanning probe microscope as claimed in claim 4, further comprising means for detecting twist of the cantilever probe.

6. A scanning probe microscope as claimed in claim 2, wherein a substantial resonance frequency of the cantilever probe (2) is made higher than a resonance frequency of the sensor cantilever (4).

7. A scanning probe microscope as claimed in claim 6, wherein means for detecting a phase and an amplitude of the cantilever probe (2) is provided independently from means for detecting a phase and an amplitude of the sensor cantilever (4).

8. A scanning probe microscope as claimed in claim 1, further comprising a position adjusting means (12).

9. A scanning probe microscope as claimed in claim 3, wherein the piezoelectric element comprises a quartz oscillator.

10. A scanning probe microscope as claimed in claim 1, wherein an optical wave guide is included in a portion of the cantilever probe (2) and one end face of the optical wave guide coincides with a front end of the probe.

11. A scanning probe microscope as claimed in claim 10, wherein the cantilever probe (2) is an optical fiber.

12. A scanning probe microscope as claimed in claim 1, wherein the cantilever probe (2) includes piezoelectric detecting means and the piezoelectric detecting means outputs a signal representative of the displacement of the probe independently from a signal of the sensor cantilever (4).

13. A scanning probe microscope as claimed in claim 12, wherein the signal representative of the displacement of the probe is constituted by signals of a phase and an amplitude of the cantilever probe (2).

14. A scanning probe microscope as claimed in claim 12, wherein piezoelectric detecting elements having reverted polarities are arranged in parallel on the cantilever probe.

15. A scanning probe microscope as claimed in claim 1, wherein a major spring element portion included in the cantilever probe (2) is arranged substantially horizontally to the surface of the sample, bending of the cantilever probe (2) caused by interaction based on the distance between a front end of the cantilever probe (2) and the surface of the sample is detected and distance control between the surface of the sample and the probe is carried out.

16. A scanning probe microscope as claimed in claim 1, wherein a major spring element portion included in the cantilever probe (2) is arranged substantially vertically to the surface of the sample, a shear force exerted between the front end of the cantilever probe (2) and the surface of the sample is sensed and distance control between the surface of the sample and the probe is carried out.

17. A scanning probe microscope as claimed in claim 1, wherein the cantilever probe (2) and the sensor cantilever (4) are brought into contact with each other while intersecting each other.

18. A scanning probe microscope as claimed in claim 4, wherein a hydrophobic treatment is carried out on both sides or one side of portions where the cantilever probe and the sensor cantilever are brought into contact with each other.

FIG.1

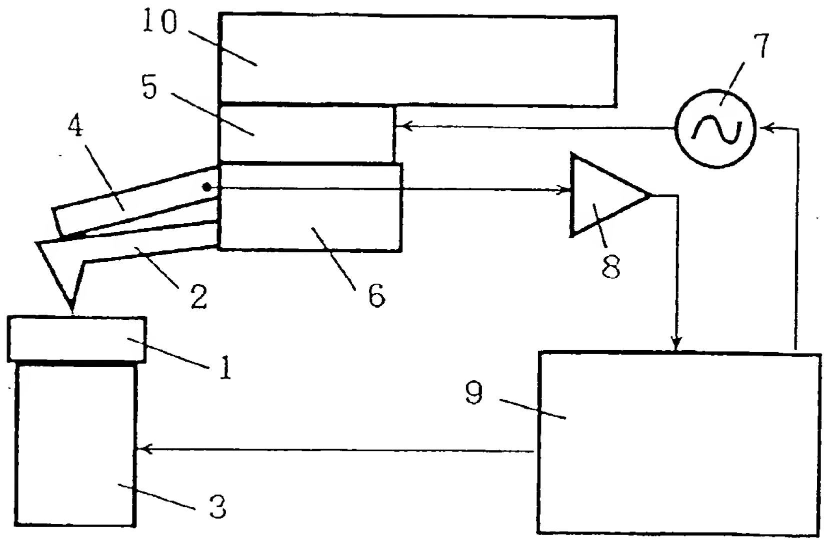


FIG.2

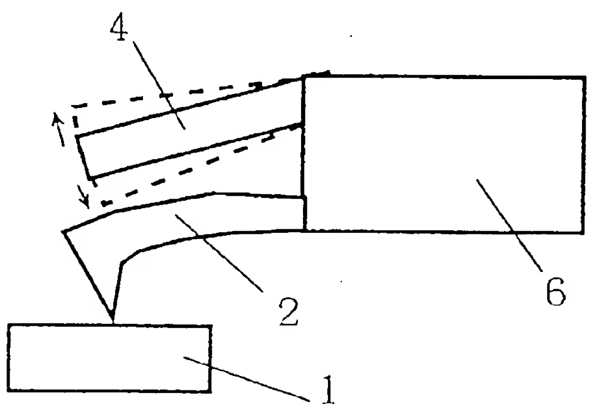


FIG.3

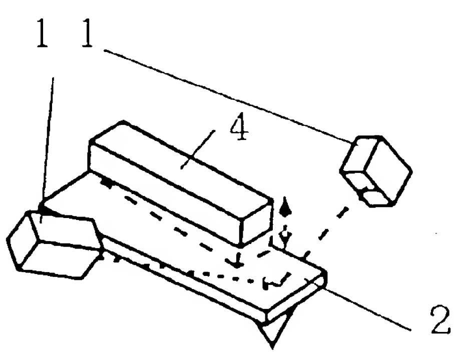


FIG.4

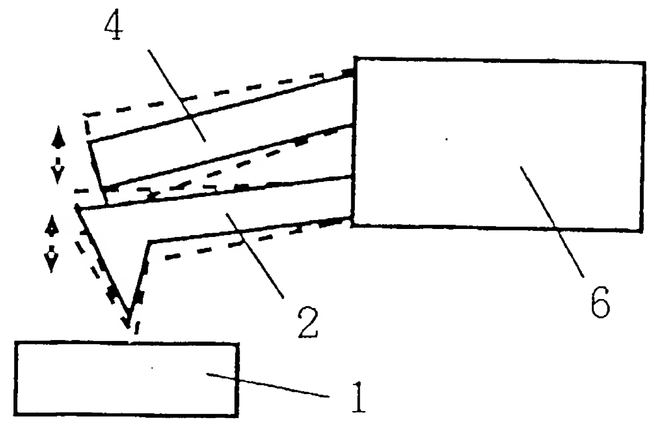


FIG.5

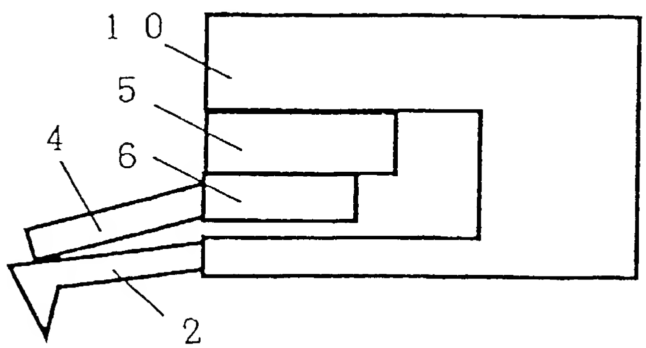


FIG.6

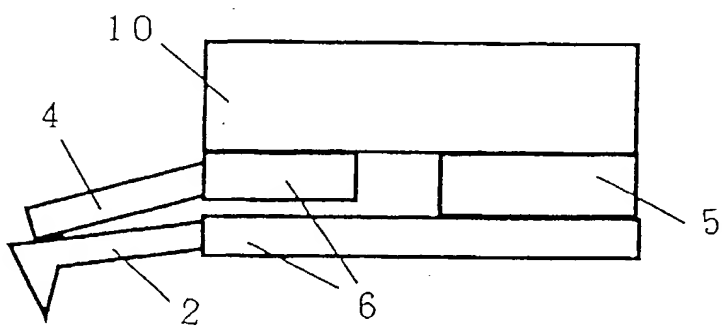


FIG.7

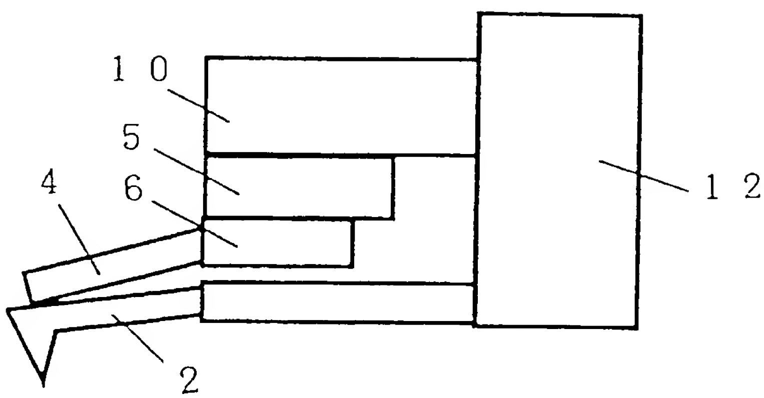
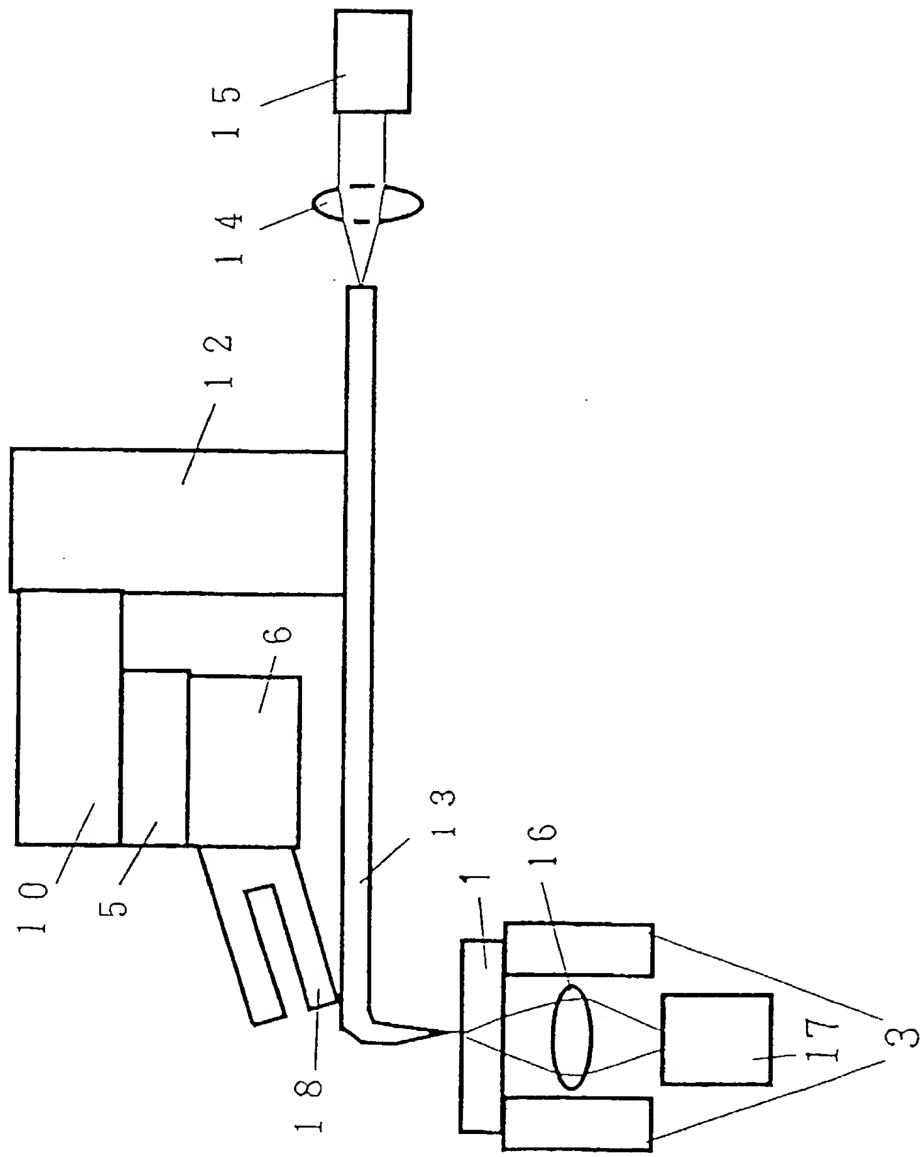


FIG. 8



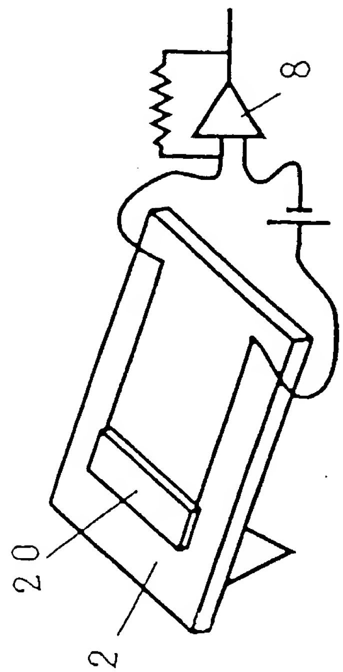


FIG.9B

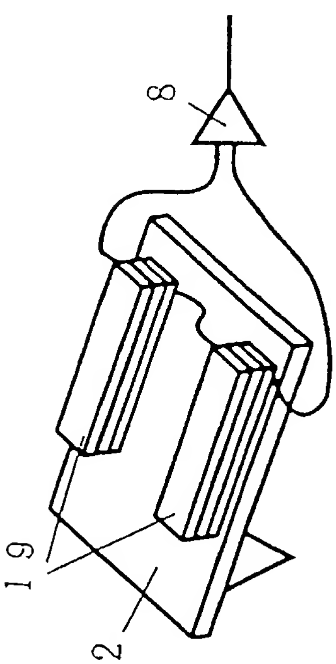


FIG.9A

FIG.10

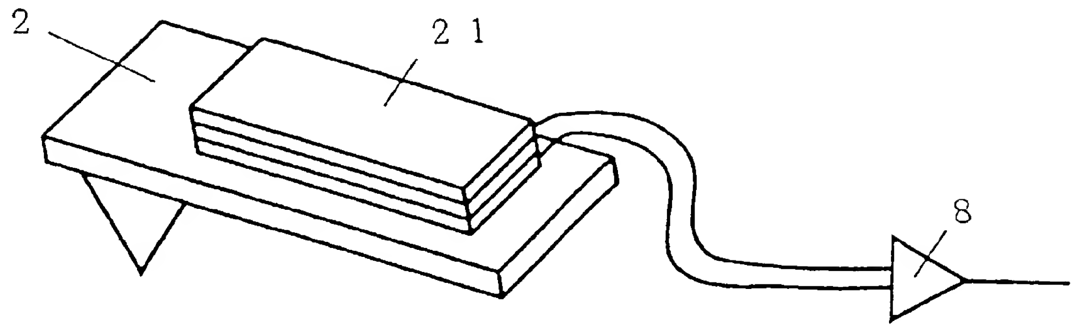


FIG.11

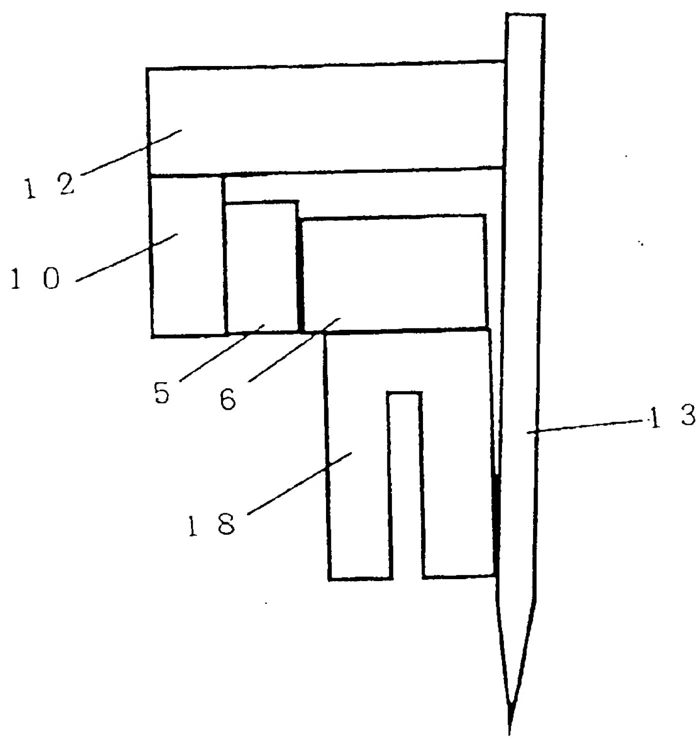
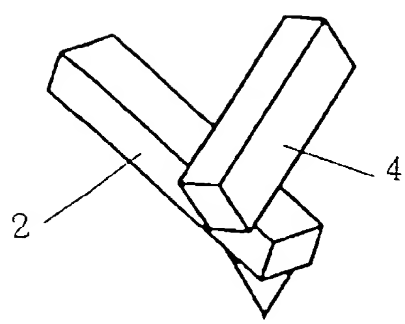


FIG.12



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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 6153

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 641 896 A (KARRAI KHALED) 24 June 1997 * the whole document *	1-3,7, 9-13,16	G01B7/34 G01N27/00
A	"DOUBLE CANTILEVER SENSOR FOR THIN-FILM HARDNESS TESTING AND MASS STORAGE APPLICATION" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 34, no. 10A, 1 March 1992, pages 194-195, XP000302273 * the whole document *	1,2	
D,A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 337 (P-1390), 22 July 1992 & JP 04 102008 A (BROTHER IND LTD), 3 April 1992 * abstract *	1-3,9	
A	US 5 338 932 A (THEODORE N DAVID ET AL) 16 August 1994 * the whole document *	1	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)**
D,A	PATENT ABSTRACTS OF JAPAN vol. 095, no. 002, 31 March 1995 & JP 06 323845 A (TADATOMO SUGA;OTHERS: 01), 25 November 1994 * abstract *	1	G01B G01N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 November 1998	Brock, T

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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